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INSTITUTE FOR DEFENSE ANALYSES

# Training Briefing for the Conduct of Technology Readiness Assessments

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**About this Publication**

This work was conducted by the Institute for Defense Analyses (IDA) under contract DASW01-04-C-0003, Task AK-2-2404, "Technology Readiness Assessments and Analyses," for the Director, Research Directorate (DRD), Office of the Director, Defense Research and Engineering. The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

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# Contents

# Introduction to the Technology Readiness Assessment (TRA) Briefing

A TRA is a formal, metrics-based process that is conducted to evaluate the maturity of technologies and their individual components (termed Critical Technology Elements (CTEs)). The assessment is prepared by a group of independent subject matter experts (SMEs), known as the Independent Review Team (IRT), using data collected by the program engineers and technical staff. The metrics used are the Department of Defense (DoD) Technology Readiness Levels (TRLs) for either hardware or software systems.

For Major Defense Acquisition Programs (MDAPs) to proceed into Milestone B, a TRL 6 (system/sub-system model or prototype demonstration in a relevant environment) is required for all CTEs—technologies deemed to be both critical to the system's functionality and new or novel. In addition, for Milestone B MDAPs, there is a statutory requirement for certification of "demonstration in a relevant environment by the Milestone Decision Authority (MDA)" (Title 10 U.S.C. §2366b). Although not in statute, TRL 7 (system prototype demonstration in an operational environment) is an exit criterion for the Engineering and Manufacturing Development (EMD) Phase for progress into Milestone C.

Therefore, it is essential (1) that assessments are prepared for and performed consistently and reliably and (2) that all team members are familiar with the rules and regulations for TRA and with the recommended best practices for performing the assessment.

The TRA briefing included in this document is designed for use by IRT members and others unfamiliar with the TRA process. The briefing should help all persons associated with the evaluation of a DoD acquisition program to become familiar with the TRA process, regulations, and requirements. A thorough understanding of the required process early in a program's maturity can guide the program toward Milestone decisions at the appropriate time. The goal is to reduce cost growth and schedule slippages that occur because of immature technologies that might enter the EMD Phase of the Defense Acquisition System.

This briefing, which should be supplemented by the *Technology Readiness Assessment (TRA) Deskbook*, also provides the Director, Research Directorate (DRD) the guidance and best practices for conducting TRAs. Several examples are offered to assist a team in selecting the CTEs and the expected metrics for proper evaluation. Procedures should be based upon the principles, guidance, and recommended best practices contained in these materials.

# Technology Readiness Assessments (TRAs)


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# Outline

- **Executive Summary**
- **Introduction**
- **Technology Maturation**
- **Identifying Critical Technology Elements (CTEs)**
  - **CTE Examples**
- **Assessing CTE Readiness**
  - **CTE Readiness Examples**
- **The TRA Report**
- **Summary**
- **Hyperlinks**
- **Backup**

# Executive Summary: Main Discussion Points

- Related legislation and policy
- Technology Readiness Assessment (TRA) Overview
  - Definition and processes
    - Succinct program definition enables determination and evaluation of Critical Technology Elements (CTEs)
  - Use of Technology Readiness Levels (TRLs)
    - Hands-on evaluation of CTEs is necessary to reach TRL 6 or higher
      - Demonstration of capability
      - Relevant environment
- Importance and outcomes
- Key player roles and responsibilities

# DoD Technology Maturation Policy Leading To Milestone B Is Unambiguous

- **Technology developed in science and technology (S&T) or procured from industry or other sources shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development**
- **Technology readiness assessments, and where necessary, independent assessments, shall be conducted**
- **If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraph 5.d.(4))**

**and • • •**

# The Policy Is Reflected as a Statutory Requirement for Certification

**Title 10 U.S.C., Subtitle A, Part IV, Chapter 139**

**§2366b. *Major defense acquisition programs: certification required before Milestone B or Key Decision Point B approval***

**(a) Certification.– A major defense acquisition program may not receive Milestone B approval, or Key Decision Point B approval in the case of a space program, until the milestone decision authority–**

**(2) Further certifies that–**

**the technology in the program has been demonstrated in a relevant environment [as determined by the milestone decision authority on the basis of an independent review and assessment by the Director of Defense Research and Engineering].**

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

MAY 0 2 2006

MEMORANDUM FOR: SEE DISTRIBUTION

SUBJECT: Implementation of Section 2366a of Title 10, United States Code

Section 2366a of title 10, United States Code, as enacted by section 801 of the National Defense Authorization Act for Fiscal Year 2006 (Pub. L. No. 109-163), requires the Milestone Decision Authority (MDA) for a Major Defense Acquisition Program (MDAP) to make certain certifications prior to Milestone B or Key Decision Point B approval.

To fulfill this requirement, the MDA, without the authority to delegate, shall sign a memorandum, subject "Program Certification," prior to signing the Acquisition Decision Memorandum (ADM). This certification memorandum shall be prepared "for the record," and shall include the statements in the attachment, without modification. If the program is initiated at a later decision point, e.g., Milestone C, a similar memorandum shall be prepared, as a matter of policy, consistent with the intent of the statute. The certification memorandum shall be submitted to the congressional defense committees, as defined at 10 U.S.C. 101_(16), with the first Selected Acquisition Report for the program after completion of the certification.

The MDA may waive one or more of components (1) through (8) of the required certification (specifically, one or more of paragraphs (1) through (5) in the attachment) for an MDAP if the MDA determines that, but for such a waiver, the Department would be unable to meet critical national security objectives. The MDA shall submit the waiver, the determination, and reasons for the determination, in writing, to the congressional defense committees within 30 days of authorizing the waiver. The MDA may not delegate this waiver authority.

In addition to the certification memorandum, the MDA will include the following statement in the ADM: "I have reviewed the program and have made the certifications required, or executed a waiver as authorized, by section 2366a of title 10, United States Code."

This policy shall apply to MDAPs approved by me and to MDAPs managed by Department of Defense Component Acquisition Executives or the Assistant Secretary of Defense for Networks and Information Integration. This requirement went into effect January 6, 2006, and shall be reflected in the next revision to Department of Defense Instruction 5000.2.

Attachment:
As stated

**Certification submitted with the first Selected Acquisition Report for the program**

# DoD Policy at Milestone C for Entry Into Production and Deployment Is Also Clear

- **DoDI 5000.02 , Enclosure 2, paragraph 7.b Entrance Criteria. Entrance into this phase depends on the following criteria:**
  - **Acceptable performance in developmental test and evaluation (DT&E) and operational assessment**
  - **Mature software capability**
  - **No significant manufacturing risks**
  - **Acceptable interoperability**
  - **Acceptable operational supportability**

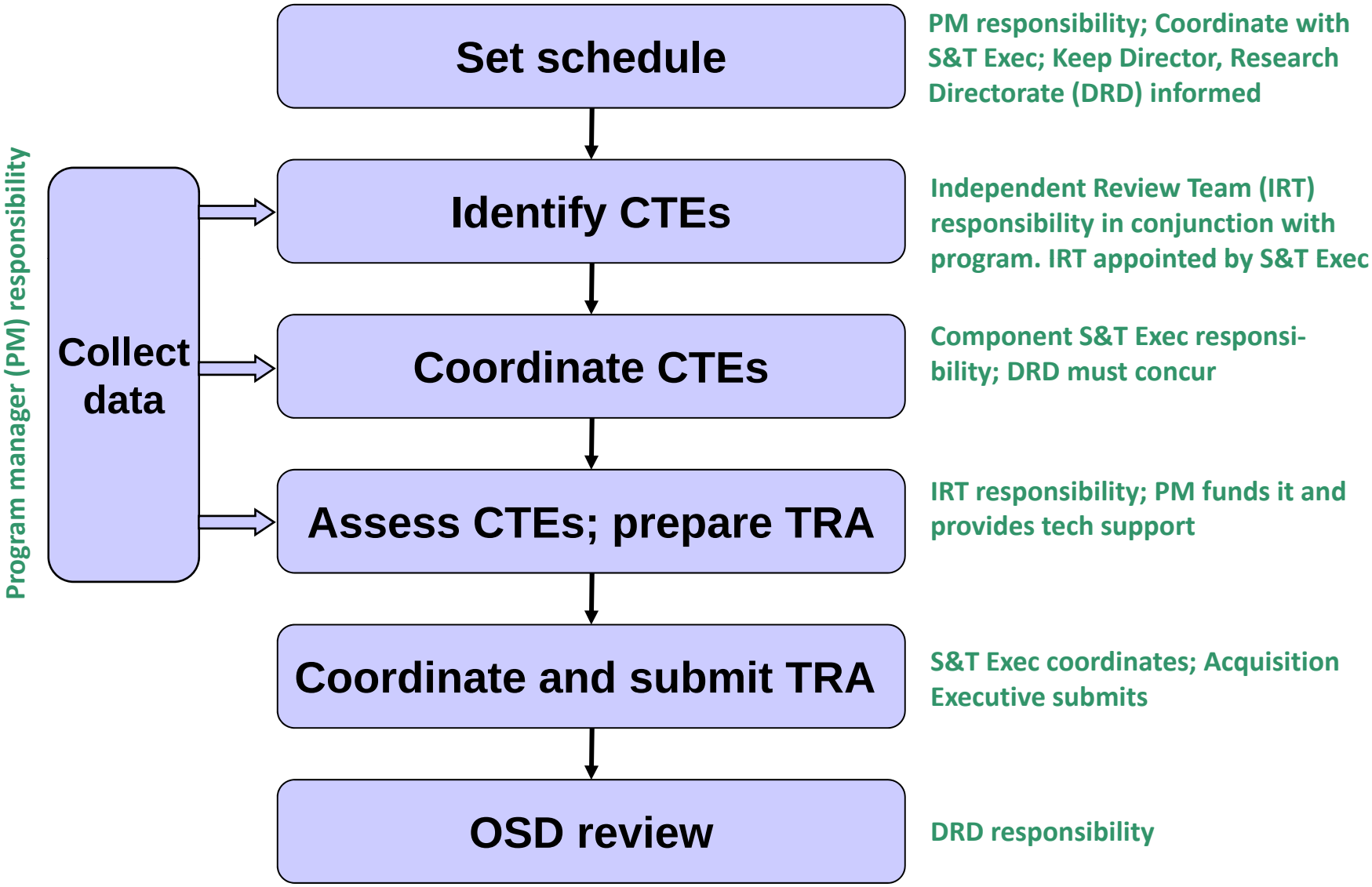
**Technology maturity policy does not distinguish Information Technologies from technologies in general**

# Technology Readiness Assessment (TRA)

- **A systematic, metrics-based process and accompanying report that**
  - **Assesses the maturity of CTEs used in systems**
  - **Uses TRLs as the metric**
    - **Adequate performance to meet program requirements must be demonstrated in the appropriate environment**
  - **Demonstrates**
    - **How the CTEs are identified**
    - **Why CTEs are important to the program**
    - **An *independent* (from the program) assessment of their maturity**

**The TRA provides feedback to the program, informs milestone decisions, and supports technology certification to Congress**

# Process Overview



# TRAs Explicitly Address Critical Technology Elements (CTEs)

- **A technology element is "critical"**
  - **If the system being acquired depends on this technology element to meet operational requirements**
    - **Within acceptable cost and schedule limits**

***and***

  - **If the technology element or its application is**
    - **Either new or novel, or**
    - **In an area that poses major technological risk during detailed design or demonstration**

**Assessment focuses on the actual technologies from the program's design**

# Hardware Technology Readiness Levels (TRLs) 6–7

| TRL | Definition | Description |
|---|---|---|
| 6 | *System/subsystem model or prototype demonstration in a relevant environment.* | Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment. |
| 7 | *System prototype demonstration in an operational environment*. | Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space). |

# Software Technology Readiness Levels (TRLs) 6–7

| TRL | Definition | Description |
|---|---|---|
| 6 | *Module and/or subsystem validation in a relevant end-to-end environment.* | Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype imple-mentations on full-scale realistic problems in which the software technology is partially integrated with existing hardware/software systems. |
| 7 | *System proto-type demonstration in an operational high-fidelity environment.* | Level at which the program feasibility of a software technology is demon-strated. This level extends to opera-tional environment prototype implementations, where critical tech-nical risk functionality is available for demonstration and a test in which the software tech-nology is well inte-grated with operational hardware/ software systems. |

# Understanding Context Is Necessary To Evaluate Maturity of CTEs

- **At Milestone B, CTE performance must be demonstrated in a relevant environment**
  - **A testing environment that simulates the technologically stressing aspects of the operational environment**
- **At Milestone C, CTE performance must be demonstrated in an operational environment**
  - **An environment that addresses all the operational requirements and specifications required of the final system to include platform/packaging**

**Identification of CTEs and the environment requires a thorough understanding of system requirements, design, and architecture**

# All Aspects of the Environment Must Be Considered

- **For Information Technology (IT)-related CTEs, the environment includes physical, logical, data, and security environments**
  - **Logical environment includes other applications, run-time (operating system, middleware), security interfaces, and Web enablement**
  - **Data environment includes formats, data rates, latency**
  - **Security environment includes firewalls, appliqués, methods or nature of attacks**

**For off-the-shelf products, the environment directly impacts the TRL**

# Basis of Technology Maturity Assessments Throughout Acquisition

| | Milestone A | Milestone B | Milestone C |
|---|---|---|---|
| Basis of CTE Identification | Early evaluation of technology maturity | Current level of design and Capabilities Development Document (CDD) requirements | Planned LRIP article (or limited deployment version of an IT system), prior TRAs, and final design |
| CTE Identification Status | Potential CTEs | CTEs – actual technologies in a preliminary design | CTEs of planned LRIP articles (or limited deployment version of an IT system) |
| Assessment Method | Evaluated in early evaluations of technology maturity and Technology Maturation Plans (TMPs) | Assessed in Milestone B TRA | Assessed in Milestone C TRA |
| Documentation | Informal submission to DRD and corresponding updates to TDS appendix | Milestone B TRA | Milestone C TRA |

# Outcomes From the TRA Process

- **Programs enter Engineering and Manufacturing Development (EMD) with mature technologies and avoid design turbulence, delay, and expense**
- **Oversight authorities certify the maturity of the technologies with confidence**
- **Systems deploy with proven technologies, thereby delivering known behavior and avoiding field fixes**
- **Programs identify technologies for additional maturation and later insertion into the system**

# PM Roles and Responsibilities

- **Plans and funds the program's risk reduction activities to ensure that CTEs reach the appropriate maturity levels**
- **Informs the Component S&T Executive of the need to conduct a TRA**
- **Funds the TRA evaluation for his program**
- **Designates a responsible individual in the program office to organize all TRA activities**
- **Prepares a draft TRA schedule and incorporates the approved version in the program's IMP and IMS**
- **Suggests to the Component S&T Executive the subject matter expertise needed to perform the TRA**
- **Ensures that the IRT is familiar with the program**
- **Identifies possible CTEs for IRT consideration**
- **Provides evidence of CTE maturity to the IRT for its assessment, including contractor data**
- **Provides technical expertise to the IRT as needed**
- **Drafts the section of the TRA report containing a brief description of the program (program/system overview, objectives, and descriptions)**

# Component S&T Executive Roles and Responsibilities

- Directs the conduct of the TRA
- Coordinates on the TRA schedule
- Nominates SMEs to be on the IRT
- Provides the DRD the credentials of all prospective IRT members and sufficient information to confirm their independence from the program
- Trains IRT members on the TRA process
- Reviews the TRA report and prepares the TRA report cover memo-randum, which may include additional technical information deemed appropriate to support or disagree with IRT findings
- Sends the completed TRA to the CAE for official transmittal to the DRD and furnishes an advance copy to the DRD
- Maintains continuity in the IRT membership for all TRAs conducted over the life of a program, to the maximum extent possible

# IRT Roles and Responsibilities

- **Keeps the Component S&T Executive and the DRD informed on progress throughout the entire TRA process**
- **Develops a list of CTE candidates in conjunction with the PM**
- **Assesses the TRLs for all CTEs**
- **Prepares (or oversees the preparation of) elements of the TRA report including (1) the IRT credentials and (2) IRT deliberations, findings, conclusions, and supporting evidence**
  - **The assessment process should not be constrained to a validation of a "program-developed" position on the TRL**

# DRD Roles and Responsibilities

- **Concurs with the TRA schedule**
- **Concurs with the composition of the IRT**
- **Reviews the candidate CTE list and identifies any changes necessary to form the final CTE list. Additions to the list can include any special-interest technologies that warrant the rigor of the formal TRA process**
- **Exercises oversight by monitoring and evaluating the TRA process and reviewing the TRA. On the basis of that review, a TRA revision may be requested or the DRD may conduct its own Independent Technical Assessment (ITA)**
- **Sends the results of its TRA review to the appropriate Overarching Integrated Product Team (OIPT) and/or the Defense Acquisition Board (DAB)**
- **Provides the DDR&E recommendations concerning certification**
- **Recommends technology maturity language for an Acquisition Decision Memorandum (ADM), noting, in particular, conditions under which the new technology can be inserted into the program**

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# What Is a TRA?

- **Systematic, metrics-based process that assesses the maturity of CTEs**
  - **Uses TRLs as the metric**
- **Regulatory information requirement for *all* acquisition programs at Milestones B and C**
  - **Submitted to DRD for ACAT ID and IAM programs, including space programs**

**Not a risk assessment**

**Not a design review**

**Does not address system integration**

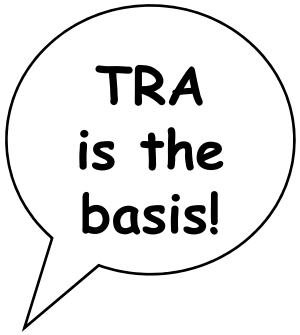
# Critical Technology Element (CTE) Defined

**A technology element is "critical" if the system being acquired depends on this technology element to meet operational requirements (within acceptable cost and schedule limits) *and if the technology element or its application* is either new or novel or in an area that poses major technological risk during detailed design or demonstration**

**CTEs may be hardware or software at the subsystem or component level**

# Why Is a Milestone B TRA Important?

- **The Milestone Decision Authority (MDA) uses the information to support a decision to initiate a program**
  - **Trying to apply immature technologies has led to technical, schedule, and cost problems during systems acquisition**
  - **TRA established as a control to ensure that critical technologies are mature, based on what has been accomplished**




- **Congressional interest**
  - **MDA must certify to Congress that the technology in programs has been demonstrated in a relevant environment at program initiation**
  - **MDA must justify any waivers for national security to Congress**

# Why Is a Milestone B TRA Important? (Continued)

- **The PM uses the expertise of the assessment team and the rigor and discipline of the process to allow for**
  - **Early, in-depth review of the conceptual product baseline**
  - **Periodic in-depth reviews of maturation events documented as verification criteria in an associated CTE maturation plan**
  - **Highlighting *(and, in some cases, discovering)* critical technologies and other potential technology risk areas that require management attention (and possibly additional resources)**
- **The PM, Program Executive Office (PEO), and CAE use the results of the assessment to**
  - **Optimize the acquisition strategy and thereby increase the probability of a successful outcome**
  - **Determine capabilities to be developed in the next increment**
  - **Focus technology investment**

# Why Is a Milestone B TRA Important? (Continued)

- **For IT systems, which rely heavily on off-the-shelf components, TRAs have increased management's focus on finding CTEs that relate specifically to IT issues (e.g., interfaces, throughput, scalability, external dependencies, integration, and information assurance)**
  - **Since many IT systems have experienced problems in these areas, the TRA has proven useful in understanding potential problems earlier in the process, when solution options are easier to adopt and less costly to implement**

**These red boxes, which appear on Slides 26, 28, 52, 72, and 77, are hyperlinked to pages toward the back of the presentation (under the "Hyperlinks" Section: see Slide 127). Opening the hyperlink will take you to the page in question. Once on that page, you'll see another red box with the word Return. Opening the Return hyperlink will take you back to the page to which it is linked.**

**IT TRA Challenges**

# Why Is a Milestone C TRA Important?

- **Reflects the resolution of any technology deficiencies that arose during EMD**
- **Serves as a check that all CTEs are maturing as planned, especially any new CTEs identified in EMD**
- **Documents successful DT&E**
- **Confirms expansion of performance envelope to "operational" environment**
- **Avoids technology-driven operational testing problems**
  - **Operational testing should focus on "effective and suitable"**

# Why Is a Milestone C TRA Important? (Continued)

- **For Major Automated Information System (MAIS) programs or software-intensive systems with no production components:**
  - **Examines plans for maintenance and upgrades to ensure that no new CTEs are involved**
  - **Identifies where new Milestone Bs are needed for future releases to initiate efforts to improve performance and determines the architectural changes necessary to support these future releases**
  - **Determines whether algorithms will transfer successfully when host platforms are moved and full-scale applications are initiated in a real operational environment**
  - **Checks technology component of information assurance (IA) before deployment**
  - **Ensures that the operational environment for systems to deploy has included duress**

Software-Intensive Systems

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# Technology Maturation Policy Leading to Milestone A

**"… the lead DoD Component(s) shall prepare an AoA [Analysis of Alternatives] study plan to assess preliminary materiel solutions, *identify key technologies*, and estimate life-cycle costs. The purpose of the AoA is to assess the potential materiel solutions to satisfy the capability need documented in the approved ICD."**

**"… The AoA *shall assess the critical technology elements (CTEs) associated with each proposed materiel solution, including technology maturity*, integration risk, manufacturing feasibility, *and, where necessary, technology maturation and demonstration needs*."**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraphs 5.c.(5) and 5.c.(6))**

# Technology Maturation Policy Leading To Milestone B Is Unambiguous

**"PMs shall reduce technology risk, demonstrate technologies in a relevant environment, and identify technology alternatives prior to program initiation."**

**(Department of Defense Directive (DoDD) 5000.01, *The Defense Acquisition System*, May 12, 2003, Certified current as of November 20, 2007, Enclosure 1, paragraph E1.1.14))**

**The TRA complements—but does not diminish—the PM's responsibility to pursue risk reduction efforts prior to program initiation at Milestone B**

# Technology Maturation Policy Leading To Milestone B is Unambiguous (Continued)

**"The project shall exit the Technology Development Phase when an affordable program or increment of militarily useful capability has been identified; the technology and manufacturing processes for that program or increment have been assessed and demonstrated in a relevant environment; manufacturing risks have been identified; a system or increment can be developed for production within a short time frame (normally less than 5 years for weapon systems); or when the MDA decides to terminate the effort. … A Milestone B decision follows the completion of Technology Development."**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraph 5.d.(7))**

# Technology Maturation Policy Leading To Milestone B Is Unambiguous (Continued)

**"The management and mitigation of technology risk, which allows less costly and less time-consuming systems development, are crucial parts of overall program management and are especially relevant to meeting cost and schedule goals.**

**Objective assessment of technology maturity and risk shall be a routine aspect of DoD acquisition. Technology developed in S&T or procured from industry or other sources shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development (see the 'Technology Readiness Assessment (TRA) Deskbook' (Reference (n)). Technology readiness assessments, and where necessary, independent assessments, shall be conducted. If technology is not mature, the DoD Component shall use alternative technology that is mature and that can meet the user's needs."**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraph 5.d.(4))**

(Ibid., Enclosure 2, paragraph 5.c.(9))

# Prototyping and Competition Policy Provides Technology Maturation Safeguards

**"Evolutionary acquisition requires collaboration among the user, tester, and developer. . . . Technology development preceding initiation of an increment shall continue until the required level of maturity is achieved, and prototypes of the system or key system elements are produced, and a preliminary design is completed."**

**"The TDS [Technology Development Strategy] and associated funding shall provide for two or more competing teams producing prototypes of the system and/or key system elements prior to, or through, Milestone B. Prototype systems . . . shall be employed to reduce technical risk, validate designs and cost estimates, evaluate manufacturing processes, and refine requirements."**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraphs 2.b and 5.c.(9))**

- **Promotes maturity via**
  - **More rigorous demonstrations in relevant environments**
  - **More comprehensive evidence of maturity**
  - **Fewer technical problems in the final design**
  - **Using prototypes for accelerated life-cycle tests**
  - **Providing insight into production issues**

# Request for Proposal (RFP) Policy Provides Technology Maturation Safeguards

**"Final RFPs for the EMD phase, or any succeeding acquisition phase, shall not be released, nor shall any action be taken that would commit the program to a particular contracting strategy, until the MDA has approved the Acquisition Strategy. The PM shall include language in the RFP advising offerors that (1) the government will not award a contract to an offeror whose proposal is based on CTEs that have not been demonstrated in a relevant environment and (2) that offerors will be required to specify the technology readiness level of the CTEs on which their proposal is based and to provide reports documenting how those CTEs have been demonstrated in a relevant environment."**

**(Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System,* December 8, 2008, Enclosure 2, paragraph 6.c.(4))**

# Open Dialogue and Feedback on AT&L Policy (AT&L Memo Aug 24 2007)

- **Policy**
  - **" . . . structure all planned competitions with one or more government industry feedback and dialogue points prior to receipt of final proposals."**
  - **"All ongoing competitions should be reviewed with a bias toward incorporating feedback and dialogue sessions before receipt of final proposals."**
- **Results of the dialogue**
  - **A high-quality, well-understood proposal**
  - **Allows the acquisition team to explain and industry to understand the fundamental factors that determine the outcome of the competition**
  - ***Provides multiple inputs for the government to define the required relevant environment for candidate CTEs and to clarify criteria with contractors***

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Attachment:
As stated

**Certification submitted with the first Selected Acquisition Report for the program**

# . . . and for Milestone B Certification Changes

**(b) Changes to Certification.–**

**(1) The program manager for a major defense acquisition program that has received certification under subsection (a) shall immediately notify the milestone decision authority of any changes to the program that –**

**(A) alter the substantive basis for the certification of the MDA relating to any of the components of such certification; or**

**(B) otherwise cause the program to deviate significantly from the material provided to the milestone decision authority in support of such certification.**

**(2) Upon receipt of information under paragraph (1), the milestone decision authority may withdraw the certification concerned or rescind Milestone B approval (or Key decision Point B approval in the case of a space program) if the milestone decision authority determines that such certification or approval is no longer valid.**

# DoD Practices To Support the Statutory Requirements

- **Early evaluations of technology maturity (prior to Milestone A) are necessary to**
  - **Provide a basis for modifying the requirements if technological risks are too high**
  - **Support the development of TMPs that show how all likely CTEs will be demonstrated in a relevant environment before preliminary design begins at the full system level**
  - **Refine the TDS**
  - **Inform the test and evaluation (T&E) community about technology maturity needs**
  - **Ensure that all potential CTEs are included in the program's risk management database and plan**
  - **Articulate external dependencies on technology base projects and define specific technologies, technology demonstration events, and exit criteria for the technology to transition into the acquisition program**

# DoD Practices To Support the Statutory Requirements (Continued)

- **USD(AT&L) practice**
  - **Programs that have immature technologies will not be initiated at Milestone B**
  - **The same standards apply to all acquisition programs**
- **As directed by 10 U.S.C. 2366b, DDR&E will provide technical advice based upon an independent review and assessment to the MDA in support of certification**
  - **For MDAPs, MAISs, and space systems, the approved TRA process, as found in the DoD *TRA Deskbook* report, will be the basis of that advice**
  - **The DDR&E-approved TRA process takes precedence over other guidance in situations where conflict would arise, pending future modification**

# TRA Processes Designed To Support This Technical Advice

- **Safeguards in place to provide the DDR&E the confidence necessary to ensure the MDA that certification can be made**
  - **To ensure that the TRA supports the certification, it must draw upon the best technical information available**
    - **As such, a generic TRA not based on the planned technical solution is not acceptable**
    - **The TRA must be based on the technologies in the system**
  - **SMEs must identify and assess the CTEs**
    - **These experts must be independent of the program (DDR&E concurrence required)**
    - **DDR&E has final say on CTE list**

# TRA Processes Designed To Support This Technical Advice (Continued)

- **Assurance that technologies have been demonstrated in a relevant environment by the winning EMD Phase contractor**
  - **To initiate programs with mature technologies, the source selection process should include a focus on technical maturity**
  - **TRAs must be performed on all the competitors in a source selection**
- **ADM language establishing conditions for CTE insertion after Milestone B**
  - **To initiate programs with mature technologies, immature CTEs may be pursued in a parallel development effort, if approved maturation plans submitted with the TRA—*on-ramp vice off-ramp for preferred approaches with undemonstrated technologies***

# Outline

- Executive Summary
- Introduction
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- Identifying Critical Technology Elements (CTEs)
  - CTE Examples
- Assessing CTE Readiness
  - CTE Readiness Examples
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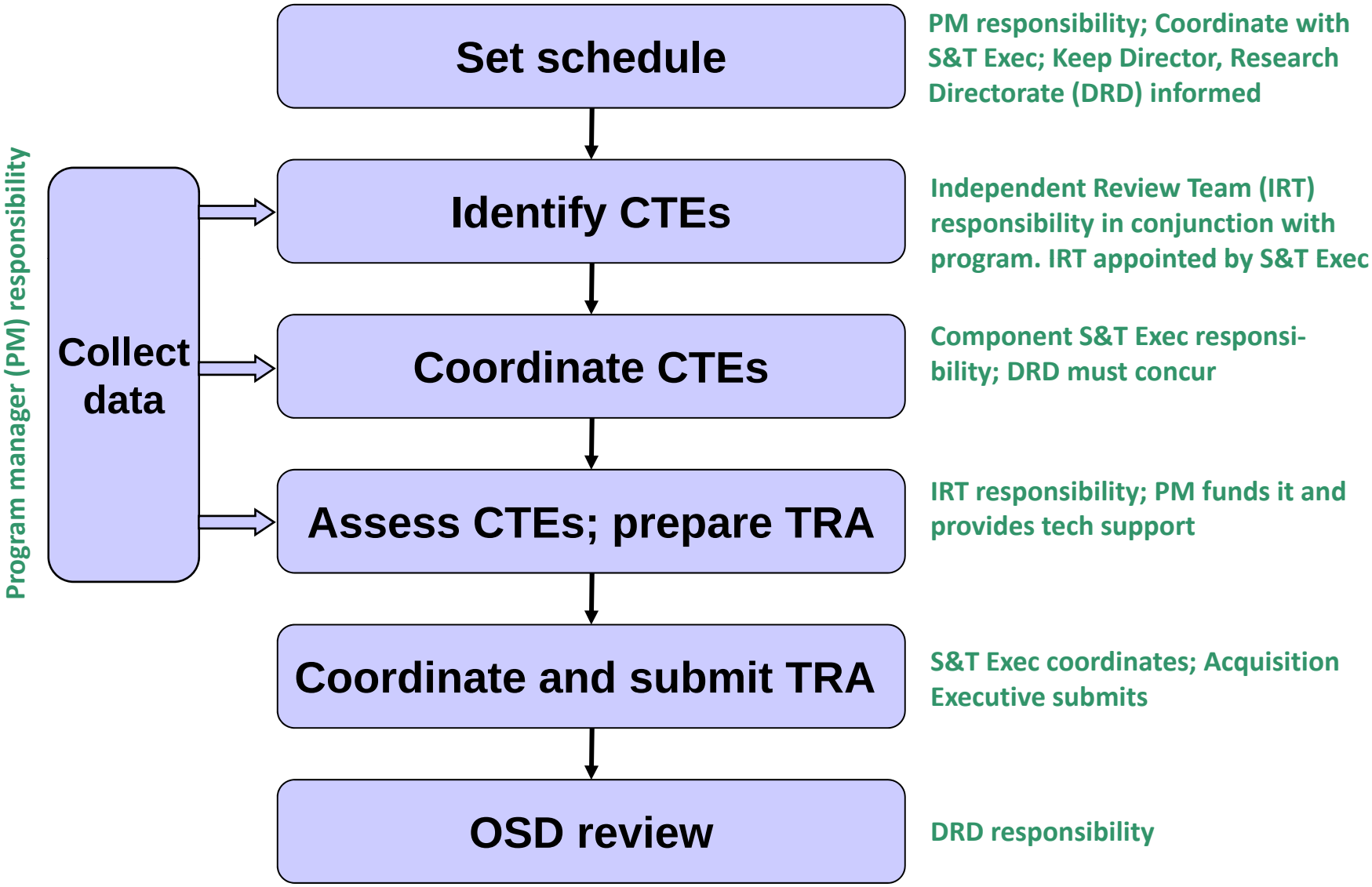
- Backup

# Process Overview



# Component S&T Executives

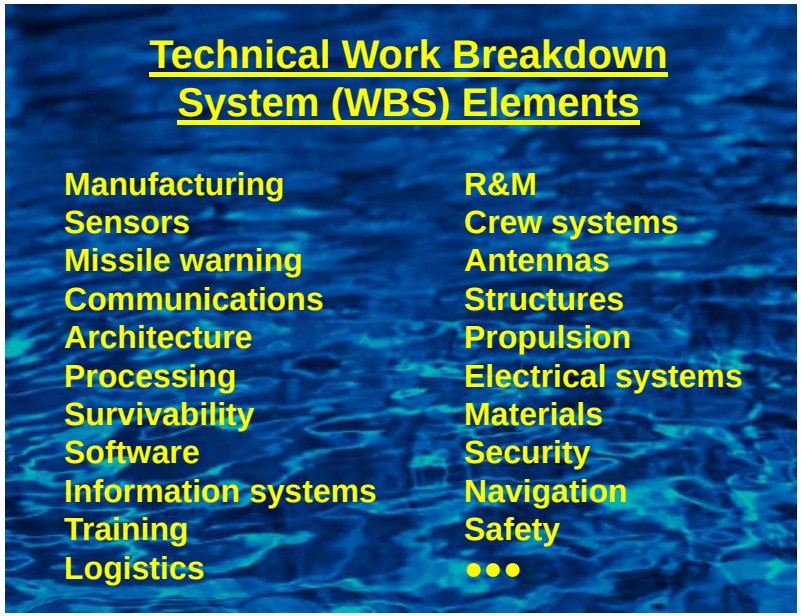
- **Army**
  - **Deputy Assistant Secretary (Research and Technology)**
- **Navy**
  - **Chief of Naval Research (CNR)**
- **Air Force**
  - **Deputy Assistant Secretary (Science, Technology, and Engineering)**
- **Defense Information Systems Agency (DISA)**
  - **Vice Director**
- **Defense Logistics Agency (DLA)**
  - **Chief Information Officer (CIO)**

**Responsible for directing the TRA**

Component S&T Executive appoints. PM funds

# Independent Review Team (IRT)

- **Selected from pool of recognized experts**
  - **DoD Components**
  - **Federally Funded Research and Development Centers (FFRDCs)**
  - **Universities**
  - **Government agencies**
  - **Industry**
  - **National Laboratories**




- **Final team membership based on technical WBS where CTEs are located**

**Responsible for performing and preparing the TRA**

# Tests for IRT Independence

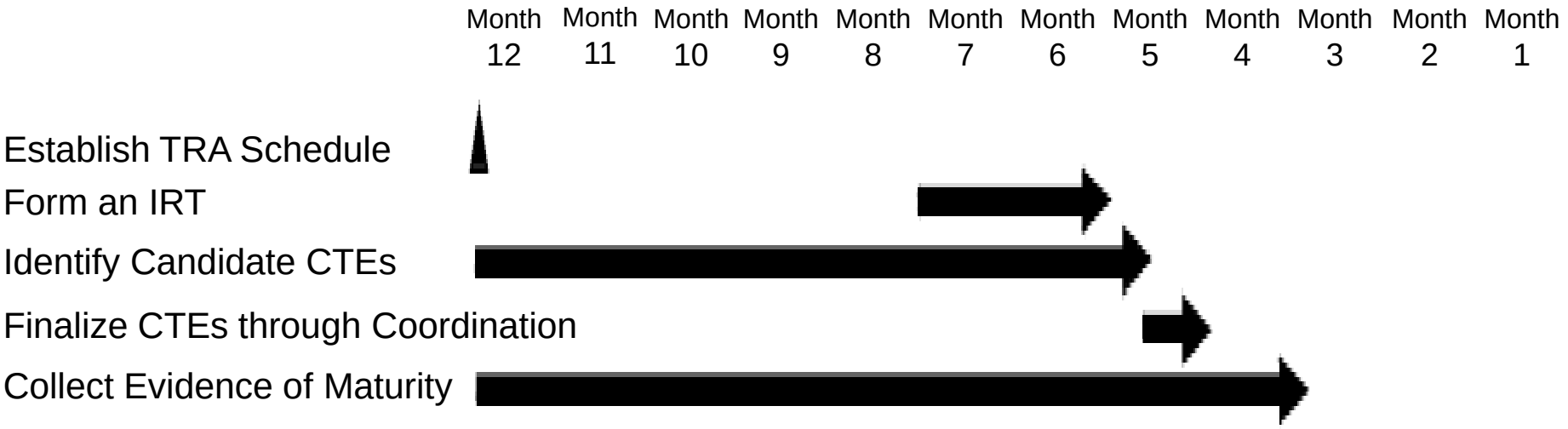
- **Members should be sufficiently independent of the developers (government or industry) as not to be unduly influenced by their opinions or have any actual or perceived biases**
- **To avoid being influenced by the PM, an IRT member should not be directly working for or matrixed to the program or be a part of any program Integrated Product Team (IPT)**

# Program Responsible for Scheduling and Funding the TRA

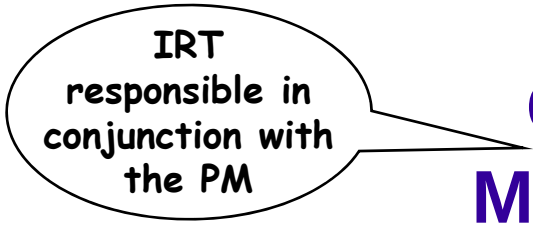
- **Establish/determine contract vehicle for funding**
  - **CTE identification**
  - **Data gathering**
  - **IRT**
    - **Training and preparation**
    - **Assessments**
    - **Report**
    - **Travel**
  - **Development of TMPs**
- **Integrate TRA plan of attack and milestones into the IMS**

IRT responsible in conjunction with the PM

# Identifying CTEs




**Schedule should be set 6 to 12 months before the Milestone review, depending on the complexity of the program**



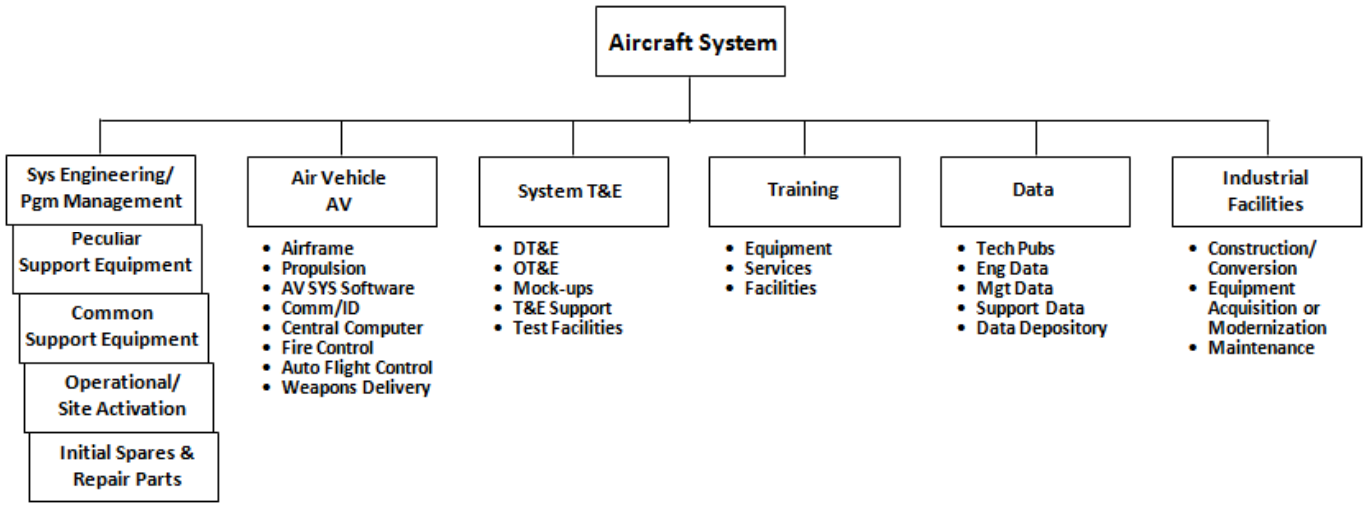

# CTE Identification: Management Process

- **Initial review**
  - **PM-led, with program office, system contractors, and government labs**
  - **Thorough, disciplined, and conservative approach**
  - **Identifies longer list of possible CTEs to ensure that no potential CTE is overlooked**
  - **Identifies information needed to determine whether the possible CTEs meet the criteria in the definition**
- **Independent review**
  - **Conducted by team of experts (i.e., the IRT)**
  - **Resolves status based on data and expertise**
  - **Develops candidate CTE list**

IRT responsible in conjunction with the PM

# CTE Identification: Technical Process

- **Use the technical WBS—or system or software architecture for IT systems—to identify CTE candidates by**
  - **Establishing the functions to be performed by each system, subsystem, or component throughout the technical WBS**
  - **Determining how the functions will be accomplished**
  - **Identifying the technologies needed to perform those functions at the desired level**




Adapted from MIL-HDBK-881, *Department of Defense Handbook: Work Breakdown Structure*, 27 January 1998

IRT responsible in conjunction with the PM

# CTE Identification: Technical Process (Continued)

The answer must be "yes"

- **Criticality to the program criteria**
  - **Does the technology have a significant impact an operational requirement, cost, or schedule?**

**See Section B.4 of the *TRA Deskbook* for other examples**

Aircraft Example

Networked Communication System Example

IRT responsible in conjunction with the PM

# CTE Identification: Technical Process (Continued)

- **Other criteria**
  - **Does this technology pose a major development or demonstration risk?**
  - **Is the technology new or novel?**
  - **Has the technology been modified from prior successful use?**
  - **Has the technology been repackaged such that a new relevant environment is applicable?**
  - **Is the technology expected to operate in an environment and/or achieve a performance beyond its original design intention or demonstrated capability?**

**At least one answer must be "yes"**

**Environment key to "new or novel"**

# Examples of Technologies Posing a Major Development or Demonstration Risk

- **The intent of both statute and policy is to avoid turbulence during EMD**
- **Technologies that are not new or novel can still pose risk of turbulence**
- **An expansive interpretation of the CTE definition will often be necessary to capture such technologies**
  - **Radiation hardening has been a repeated source of difficulty during the development of satellite systems**
  - **Force protection will attract high-level attention throughout the development of manned combat systems**


# CTE Identification: Coordination Process

- **DRD reviews the candidate CTE list developed by the IRT and identifies any changes necessary to form the final CTE list**
- **Additions to the list can include any special-interest technologies that warrant the rigor of the TRA process**

# Environment Examples

- **Physical Environment** – For instance, mechanical components, processors, servers and electronics; kinetic and kinematic; thermal and heat transfer; electrical and electromagnetic; climatic/weather, temperature, particulate; network infrastructure
- **Logical Environment** – For instance, software (algorithm) interfaces; security interfaces; Web-enablement
- **Data Environment** – For instance, data formats and databases; anticipated data rates, data delay, and data throughput; and data packaging and framing
- **Security Environment** – For instance, connection to firewalls; security appliqués; rates and methods of attack
- **User and Use Environment** – For instance, scalability; upgradeability; user behavior adjustments; user interfaces; organization change/realignments that have system impacts; implementation plan


**Others may be relevant**

# Sample Questions To Determine If Environment Is New or Novel

- **Is the physical/logical/data environment in which this CTE has been demonstrated similar to the intended environment? If not, how is it different? Is the difference important?**
- **Is the CTE going to be operating at or outside the usual performance envelope? Do specifications address the behavior of the CTE under these conditions? What is unique or different about the proposed operations environment?**
- **Do test data, reports, or analysis that compare the demonstrated environment to the intended environment exist? If modeling and simulation (M&S) is an important aspect of that comparison, are the analysis techniques common and generally accepted?**

**See Section B.3.2 of the *TRA Deskbook* for more questions**

# How Many CTEs Should Be Identified?

- **Do not miss any**
  - **System performance, program schedule, and cost could be jeopardized**
- **Do not be overly conservative**
  - **If too many non-critical technologies are treated as CTEs, energy and resources may be diverted from the few technologies that require an intensive maturation effort**

**If a disciplined process leads to an inordinate number of CTEs, the proposed development program may be too far-reaching**

# Data Collection

- **PM collects evidence of CTE maturity**
  - **Ongoing process throughout CTE identification**
  - **May include component and subsystem test descriptions, analyses, environments, and results**
  - ***Best Practice: evidence should be as objective as possible and align with current TMP's documented verification criteria for achieving the next level***

**Keep DRD informed. May suggest additional CTEs**

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# CTEs May Not Be Glamorous

***Ship Example***

- **A highly maneuverable, load-carrying vehicle capable of motion in any direction was identified as a CTE**
  - **Intended for manual and autonomous use**
- **Sensors and software for autonomous travel will be new, *as will the vehicle's use within the sea environment***
- **This critical technology provides significant capability enhancement over existing material handling equipment and supports the reduced manning goal of the ship program**

# CTEs May Not Be Associated With a Key Performance Parameter (KPP)

## *Ground Vehicle Example*

- **KPPs concerned interoperability and transportability of the vehicle itself**
- **Operational Requirements Document (ORD) called for integration of a standoff chemical agent detector**
  - **The mission-essential function is to detect and classify**
  - **A passive infrared (IR) detection system that detects the presence or absence of chemical warfare agents was planned for the vehicle**
  - **The detection system was appropriately identified as a CTE**

**Criticality to the program test is as follows:**
***Does the technology directly impact an operational requirement*?**

# CTEs May Not Be Associated With a KPP (Continued)

## *Sensor Example*

- **Two technologies were inappropriately excluded**
  - **Hyperspectral imagery: New technology. Not required to meet KPPs**
  - **Aided Target Recognition (ATR) algorithms: Used to support throughput of synthetic aperture radar (SAR) imagery. Not required to meet KPPs**

**Enabling technologies should not be excluded from being CTEs**

# A CTE May Be in Another Program

## *Ground Vehicle Example*

- **A vehicle-mounted, on-the-move, chemical agent detector was identified as a CTE**
  - **It impacted an operational requirement *and***
  - **It was new**
- **The proposed solution was a passive IR detection system that detects the presence or absence of chemical warfare agents and was an independent program initiated in September 1996 under the Joint Program Office for Chemical, Biological, Radiological, and Nuclear Defense**

**The term of art is "External Dependency":**
**They must be included in the TRA but are not required to be mature**

# Consider All Environments

- A “tactical” logistics system bought commercial off-the-shelf (COTS) software and hardware to implement inventory control in theater. Prior to Milestone B, the program briefed the IRT on the intended use of the system: in large logistics bases and theater HQ to track supplies locally
- Based on the program’s brief, the IRT found one CTE
- Just prior to Milestone B, a user professed the need to use the system in a bandwidth-disadvantaged, intermittent-connectivity, high-latency environment where ruggedization was required. This need was not inconsistent with the term “tactical” as defined in the CDD, but this user’s intent was new to the program and to the IRT
- The Milestone B date was delayed until the more difficult definition of “tactical” environment could be established

# When to Aggregate CTEs

- **A communications program had three candidate CTEs in the network management category prior to Milestone B**
  - **CTE (1) was a software module that diagnosed network health by building a database on the network manager's control station**
  - **CTE (2) stored information on those links that were able send user traffic**
  - **CTE (3) stored information on network routing**
- **By Program Design Review (PDR), no data were to be stored on the network manager's control station in favor of a distributed solution. Also, the information on user traffic and routing was to be collected by the same module and stored in the same database**
- **At Milestone B, DDR&E agreed with the IRT decision to remove CTE (1) and aggregate CTE (2) and CTE (3) into a single CTE called "Routing-Status"**

# When to De-aggregate CTEs

- An IT program had to automate data transfer from one legacy system to another
- The program proposed to build an edge-device, write the software to control it, and integrate it with legacy systems. At Milestone B, the IRT identified the edge-device as a CTE and assessed it as TRL 6
- Before Milestone C, the IRT deadlocked on whether the edge device was TRL 7. The device was like a laptop (i.e., it plugged into the interfaces and the software ran on it), but all the software functionality had not been tested with all legacy systems
- The solution was to break the CTE into a hardware CTE (TRL 7) and a software CTE (TRL 6). More testing was done on the software

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IRT responsible

# Assessing CTE Readiness

| Month 12 | Month 11 | Month 10 | Month 9 | Month 8 | Month 7 | Month 6 | Month 5 | Month 4 | Month 3 | Month 2 | Month 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|

Assess CTE Maturity

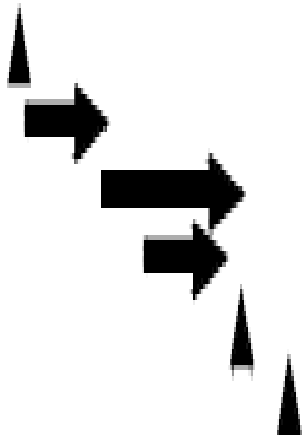
Prepare, Coordinate, Submit TRA Report

DRD Review & Evaluation

Perform Independent TRA (if necessary)

Prepare Evaluation Memo

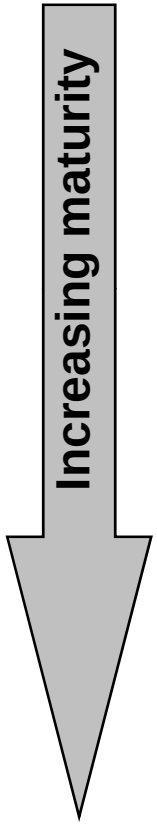
Milestone Review



# TRL Overview

- **Measures technology maturity**
- **Indicates what has been accomplished in the development of a technology**
  - **Theory, laboratory, field**
  - **Relevant environment, operational environment**
  - **Subscale, full scale**
  - **Breadboard, brassboard, prototype**
  - **Reduced performance, full performance**
- **Does not indicate that the technology is right for the job, that application of the technology will result in successful development of the system, or how difficult the application might be to implement**

# Hardware TRLs: Assessment Criteria




1. Basic principles observed and reported
2. Technology concept and/or application formulated
3. Analytical and experimental critical function and/or characteristic proof of concept
4. Component and/or breadboard validation in a laboratory environment
5. Component and/or breadboard validation in a relevant environment
6. System/subsystem model or prototype demonstration in a relevant environment
7. System prototype demonstration in an operational environment
8. Actual system completed and qualified through test and demonstration
9. Actual system proven through successful mission operations

See additional hardware examples in Section C.2 of the *TRA Deskbook*

Hardware CTE Example

# TRL 4 Hardware
# Minimum Maturity at Milestone A

- **Definition:** Component and/or breadboard validation in a laboratory environment
- **Description:** Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of "ad hoc" hardware in the laboratory
- **Supporting Information:** System concepts that have been considered and results from testing laboratory-scale breadboard(s). References to who did this work and when. Provides an estimate of how breadboard hardware and test results differ from the expected system goals

# TRL 5 Hardware

- **Definition:** Component and/or breadboard validation in a relevant environment
- **Description:** Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components
- **Supporting Information:** Results from testing a laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. How does the "relevant environment" differ from the expected operational environment? How do the test results compare with expectations? What problems, if any, were encountered? Was the breadboard system refined to more nearly match the expected system goals?

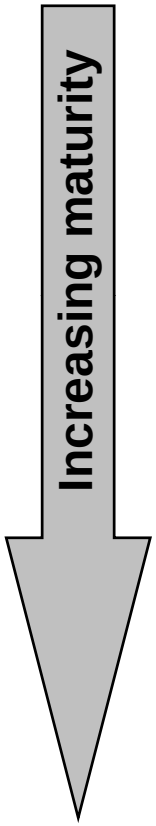
# TRL 6 Hardware
# Minimum Maturity at Milestone B

- **Definition:** System/subsystem model or prototype demonstration in a relevant environment
- **Description:** Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment
- **Supporting Information:** Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. How did the test environment differ from the operational environment? Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?

# TRL 7 Hardware
# Minimum Maturity at Milestone C

- **Definition:** System prototype demonstration in an operational environment
- **Description:** Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g., in an aircraft, in a vehicle, or in space). Examples include testing the prototype in a test bed aircraft
- **Supporting Information:** Results from testing a prototype system in an operational environment. Who performed the tests? How did the test compare with expectations? What problems, if any, were encountered? What are/were the plans, options, or actions to resolve problems before moving to the next level?

# Software TRLs: Assessment Criteria




1. Basic principles observed and reported
2. Technology concept and/or application formulated
3. Analytical and experimental critical function and/or characteristic proof of concept
4. Module and/or subsystem validation in a laboratory environment (i.e., software prototype development environment)
5. Module and/or subsystem validation in a relevant environment
6. Module and/or subsystem validation in a relevant end-to-end environment
7. System prototype demonstration in an operational high-fidelity environment
8. Actual system completed and mission qualified through test and demonstration in an operational environment
9. Actual system proven through successful mission proven operational capabilities

See additional software examples in Section C.3 of the *TRA Deskbook*

Software CTE Example

# TRL 4 Software
# Minimum Maturity at Milestone A

- **Definition:** Module and/or subsystem validation in a laboratory environment (i.e., software prototype development environment)
- **Description:** Basic software components are integrated to establish that they will work together. Their efficiency and robustness are relatively primitive compared with the eventual system. Architecture development initiated to include interoperability, reliability, maintainability, extensibility, scalability, and security issues. Emulation with current/ legacy elements as appropriate. Prototypes developed to demonstrate different aspects of eventual system
- **Supporting Information:** Advanced technology development, stand-alone prototype that solves a synthetic full-scale problem or a stand-alone prototype that processes fully representative data sets

# TRL 5 Software

- **Definition:** Module and/or subsystem validation in a relevant environment
- **Description:** Level at which software technology is ready to start integration with existing systems. The prototype implementations conform to target environment/interfaces. Experiments with realistic problems. Simulated interfaces to existing systems. System software architecture established. Algorithms run on a processor(s) that has the characteristics expected in the operational environment
- **Supporting Information:** System architecture diagram around technology element with critical performance requirements defined. Processor selection analysis, Simulation/Stimulation (Sim/Stim) Laboratory buildup plan. Software placed under configuration management. COTS/GOTS (government off-the-shelf) components in the system software architecture are identified

# TRL 6 Software
# Minimum Maturity at Milestone B

- **Definition:** Module and/or subsystem validation in a relevant end-to-end environment
- **Description:** Level at which the engineering feasibility of a software technology is demonstrated. This level extends to laboratory prototype implementations on full-scale realistic problems in which the software technology is partially integrated with existing hardware/software systems
- **Supporting Information:** Results from laboratory testing of a prototype package that is near the desired configuration in terms of performance, including physical, logical, data, and security interfaces. Comparisons between tested environment and operational environment analytically understood. Analysis and test measurements quantifying contribution to system-wide requirements such as throughput, scalability, and reliability. Analysis of human-computer (user environment) begun

# TRL 7 Software
# Minimum Maturity at Milestone C

- **Definition:** System prototype demonstration in an operational, high-fidelity environment
- **Description:** Level at which the program feasibility of a software technology is demonstrated. This level extends to the operational environment prototype implementations, where critical technical risk functionality is available for demonstration and a test is available in which the software technology is well integrated with operational hardware/software systems
- **Supporting Information:** Critical technological properties are measured against requirements in a simulated operational environment

# TRL 6 and TRL 7 Comparison

| | TRL 6 | TRL 7 |
|---|---|---|
| ***By when should a CTE be at least …?*** | Milestone B | Milestone C |
| ***What is being assessed?*** | CTE as part of a system/subsystem model or prototype | CTE as part of a system prototype |
| ***What is the assess-ment environment?*** | Relevant environment | Operational environment |
| ***Sample environment*** | High-fidelity lab or simulated, operational environment | Test bed or test range facility |

# Milestone B Requirement: Demonstration or Validation in a Relevant Environment (TRL 6)

**Relevant Environment: a *set of stressing conditions representative of the full spectrum of relevant operational employments*, which are applied to a CTE as part of a component (TRL 5) or system/subsystem (TRL 6) model or prototype *to identify whether any design changes or fixes are needed to support the required (threshold) functionality***

# Milestone C Requirement: Demonstration or Validation in an Operational Environment (TRL 7 or 8)

**Operational Environment: a *set of operational conditions, representative of the full spectrum of operational employments*, which are applied to a CTE as part of a system prototype (TRL 7) or actual system (TRL 8) to *identify whether any previously unknown or undiscovered design problems will impact the required (threshold) functionality***

# Demonstration or Validation of a Technology in an Operational Environment

- **Requires successful trial testing that either**
  - **Shows that the technology satisfies functional need across the full spectrum of operational employments or**
  - **Shows that the technology satisfies the functional need for some important operational employment and uses accepted techniques to extend confidence over all required operational employments**

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# Assessing COTS Hardware
## *The Situation*

- **TRA on an upgrade to a major DoD aircraft**
- **CTEs identified and grouped based on WBS categories**
- **Upgrade centered on use of commercial engines and pylons that have had extensive commercial usage**
  - **Pylons, wing attachments, and thrust reversers were used commercially in similar application**
  - **Military application included use of thrust reversers in flight**
  - **Most algorithms in engine software unchanged**
- **Initial assessments of TRL 8 or 9 for propulsion**

# Assessing COTS Hardware (Continued)
## *What Happened*

- **Discoveries after CDR**
  - **Pylon and wing attachment not strong enough for asymmetric thrust reversal in flight**
  - **Redesign #1: Put cables across bottom of engine**
    - **Maintenance burden and risk of mispositioning the thrust reversers**
  - **Redesign #2: Connect thrust reverser sections across top of engine**
    - **Structure of pylon changed slightly as well**

# Assessing COTS Hardware (Continued)
## *Lessons Learned*

- **Expansive definitions of the "relevant" or "operational" environment will forestall problems**
- **COTS equipment, when adopted, must have its usage base rigorously compared against operational environments when identifying or assessing CTEs**

**Turbulence during design can result from any undemonstrated aspect of the technology/environment combination**

# Assessing COTS Software
## *The Situation*

- **An identity management program was assessed by an IRT prior to Milestone C**
  - **The IRT conducted an industry survey and assessed some small DoD pilot programs**
  - **The technology scaled to the DoD size, and the same commercial sector functions were to be used**
  - **The IRT determined that all the CTEs were TRL 9 based on their commercial use**

# Assessing COTS Software (Continued)
## *What Happened*

- **DDR&E agreed with the IRT's conclusions on scalability; however, DDR&E noted that the security environment was different**
  - **In this case, important security aspects of the operational environment were overlooked. The DoD faces threats that private entities do not face, and it has a unique risk tolerance (it must self-ensure at the cost of life and death)**
  - **When the CTEs were reassessed (including the DoD security environment), the IRT concluded that these CTEs were TRL 6. They were demonstrated to provide identity management capability—but only in a benign environment**

# Assessing COTS Software (Continued)
## *Lessons Learned*

- **The IRT did a good job on the assessment but used incorrect standards for a successful demonstration in an operational environment**
  - **The operational environment must include the full spectrum of stressing events that can be expected in DoD use**
  - **Ostensibly subtle differences in the way COTS software is used can actually lead to great technical risk with DoD use**

# Getting the Right Data
## *The Situation*

- **A communications program was approaching Milestone B**
  - **The program scheduled system-wide test events that assessed overall system capability and could be measured against KPPs**
  - **The CTEs were a disaggregated set of technologies that supported the KPPs and other requirements**
  - **When the test reports were sent to the IRT, not enough data were available to determine if each CTE had performed correctly. For example, a CTE related to monitoring communications links was supposed to demonstrate accuracy and timeliness. The percentage of messages transmitted by the all the links was in line with the KPPs, but the IRT determined that the TRL of the monitoring CTE could not be determined because no one had kept track of how long updates took or whether these updates were consistent with the ground truth**

# Getting the Right Data (Continued)
## *What Happened*

- **The program was required to retest the monitoring CTE and the other CTEs, at great monetary cost**
  - **After retesting, the monitoring CTE was found to be TRL 6**
  - **Another CTE was found not to be TRL 6 because in certain conditions that were likely in battle but occurred a just few times during the system-wide tests, the CTE failed to perform consistently**
  - **The program and contractor installed a fix. The failed CTE was rated TRL 6 four months later**

# Getting the Right Data (Continued)
## *Lessons Learned*

- **The maturity assessments used by DDR&E to establish CTE maturity often need more information than measures of system-wide capability**
- **TRLs are established by meeting objective standards explicitly stated, or derived from, KPPs, other require-ments, policy, regulations, and even law**

# A Good Logic Chain
## *The Situation*

- **A classified IT program was approaching Milestone B**
  - **The program tried to schedule tests that included full-scale, realistic problems, but the contractor had fallen behind on the delivery of key items**
  - **The IRT felt that TRL 6 could not be established without demonstrating the CTEs in these full-scale realistic problems**
  - **Further, the requirements for the some CTEs were so general that the IRT did not know how to make a quantitative objective assessment**

# A Good Logic Chain (Continued)
## *What Happened*

- **DDR&E agreed with the IRT but pointed out that technologies similar to the CTEs may have been demonstrated in other programs. Also, DDR&E said that the IRT should develop an expert position on the quantitative standards for CTEs**
  - **The IRT and the Program Management Office (PMO) cooperated to search external records and reports that were related to the technology in the program**
  - **The IRT found that similar technology had been demonstrated in a slightly different context. The TRA included a compelling chain of logic that indicated that these external tests were sufficient to establish TRL 6 for the program's CTEs. The chain of logic described the similarities and differences in the intended use, the test events, and the metrics for successful demonstrations**
  - **To solve the ambiguous requirements problem, the IRT used law, DoD-wide policy, the organizational regulations, and even operational data to determine what quantitative measures and standards matched the qualitative words in the programmatic requirements documents**

# A Good Logic Chain (Continued)
## *Lessons Learned*

- **By presenting complete, clear, compelling, and factual arguments, the TRA put together disparate pieces of evidence to establish TRL 6 for all CTEs**
- **When faced with a set of ambiguous or subjective requirements, additional sources (to those of the program's requirements documents) can be used to clarify what a constitutes a successful demonstration**

# Scalability
## *The Situation*

- **A communications networking program was approaching Milestone B**
  - **The program scheduled full-scale, realistic tests**
  - **The IRT analysis compared physics-based M&S predictions to measured performance**
  - **The results showed that antenna and network "self-healing" CTEs were performing in the field as predicted. The results also showed that the CTEs related to autonomous network management were not performing as predicted. Further, CTEs related to video conferencing were trending as predicted but were not meeting the standards for a successful demonstration**

# Scalability (Continued)
## *What Happened*

- **The DDR&E memo to the MDA outlined the situation. The MDA restructured the program**
  - **The antennas and self-healing CTEs were incorporated into a new increment. They progressed rapidly to TRL 7 and were fielded to the warfighter**
  - **The autonomous network management CTEs continued technology development and ultimately revealed problems in both the CTEs and the models. They have since passed Milestone B, and the improved models are in wide use**
  - **The video conferencing CTEs were shown to have reached fundamental scaling limits given that were not captured in the modeling. The original predictions of performance were based on assumptions about commercial networks with commercial traffic profiles. The technology is currently back in the tech base**

# Scalability (Continued)
## *Lessons Learned*

- **Scalability must be demonstrated at Milestone B. M&S can contribute to the demonstration, but the models must be reliable and predictive for the relevant environment**
- **When a program has mature and immature technology heading into Milestone B, the TRA can assist in getting the technology that is “ready” to the warfighter sooner and refocus tech development efforts on the immature parts**

# Information Assurance (IA)
## *The Situation*

- **An intrusion detection system was approaching Milestone C**
  - **The program had scheduled system-wide integration testing in a controlled environment but had not scheduled adversarial testing**
  - **The IRT analysis assessed no greater than TRL 6 because the environments included in testing were not operational environments. As components or subsystems, the CTEs had been tested under duress for TRL 6, but they had not been tested as they would have to operate in a fully integrated system. The testing did not include the kind of threats the system should expect to face**

# IA (Continued)
## *What Happened*

- **DDR&E agreed with the IRT. The CTEs had been demonstrated under duress individually but not as a system in an operational environment**
  - **A Red-Team effort was started to challenge the system**
  - **The results were important and informative**

# IA (Continued)
## *Lessons Learned*

- **Information systems often enter initial operational test and evaluation (IOT&E) in actual-use pilots. Undetected flaws in the system can allow adversaries access to the DoD network**
- **Since implementation is a critical part of security and the programs that comprise the Global Information Grid (GIG) have many interdependencies, adversarial testing to assess IA-related CTEs in a cyber warfare environment is critical at Milestone C**

# Maturity Demonstrated by Others May Not Suffice

- **Early in the Javelin development, the prime contractor produced an effective system; however, the focal planes could not be produced by the prime in sufficient quantity or with sufficient yield**
  - **A different IR contractor did have the ability and was brought on as a subcontractor/supplier of the focal planes**
- **To establish maturity, it is not sufficient for "someone" to be able to demonstrate the needed performance. The technology performance must be deliverable by the performing team**

# Non-Complex Technology Is Unacceptable Rationale for TRL 6 or Higher

***Example***

- **Subsystem identified as CTE**
  - **A similar or existing prototype has not demonstrated an ability to perform the subsystem's mission from the example platform**
- **Inappropriately assessed at TRL 6**
  - **Although the subsystem is in concept design, its low technical complexity will allow the use of known and proven fabrication methods and materials**

**Demonstration of a prototype in a relevant environment is precondition for TRL 6**

# System Level Demonstration Required for TRL 7 or Higher

## *Software-Intensive System Example*

- **TRA inappropriately identified two CTEs as TRL 7 and two as TRL 8**
- **The rationale for the TRL scores was that the systems being scored are currently in operational use and have already been through the acquisition process. Integration into a common environment is the major area to be addressed for each critical technology.**
- **The IRT approached the integration issue from the standpoint that integration will occur during EMD, and, therefore, the TRL score is based on the individual critical technology**
- **CTEs should have been assessed to be TRL 6**

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- Executive Summary
- Introduction
- Technology Maturation
- Identifying Critical Technology Elements (CTEs)
  - CTE Examples
- Assessing CTE Readiness
  - CTE Readiness Examples
- The TRA Report
- Summary
- Hyperlinks
- Backup

# TRA Report

- **Technical report**
  - **Short description of the program**
  - **IRT credentials**
  - **IRT deliberations, findings, conclusions, supporting evidence, and major dissenting opinions**
  - **Other technical information deemed pertinent by the Component S&T Executive**
- **Cover letter signed by the Component S&T Executive**

IRT oversees preparation

# Technical Report Contents

20%

- 1.0 Purpose of This Document
- 2.0 Program Overview
  - 2.1 Program Objective
  - 2.2 Program Description, Including Spirals Covered
  - 2.3 System Description

80%

- 3.0 Technology Readiness Assessment
  - 3.1 Process Description
  - 3.2 Critical Technologies
  - 3.3 Assessment of Maturity
    - 3.3.1 First CTE or Category of Technology
    - 3.3.2 Next CTE or Category of Technology
  - 3.4 Summary of TRLs by Technology
- 4.0 Conclusion

Focus is not programmatic

**A TRA is a technical report with references**

# TRA Technical Report Section 3.1 Should Identify IRT Members

## *Operational Planning System Example*

- **The TRA IRT is composed of system engineers from an FFRDC and Goodness University. None of their employers have a contract with the program office. The four principals leading the assessment are**
  - **Mr. X, FFRDC Corporation. Mr. X has 26 years of computer systems experience and 16 years of experience in the environment. He holds a Bachelor of Arts in Quantitative Methods from the University of X and a Master of Science in Information Systems from the School of Engineering from the University of X**
  - **Mr. Y, FFRDC Corporation. Mr. Y has 24 years of computer systems experience and 9 years of experience in the environment. He holds a Bachelor of Science in Computer Science from the University of Y and a Master of Science in Management Information Systems from the University of Y**
  - **Mr. Z, FFRDC Corporation. Mr. Z has 7 years of computer systems experience. He holds a Bachelor and Master of Science in Electrical Engineering and Computer Science from the Institute of Z**
  - **Dr. A, Goodness University, Senior Technology Consultant, College of Information Science and Technology**

# TRA Technical Report Section 3.3
# Assessment of Maturity

- **Include all the IRT's deliberations, findings, and conclusions**
- **Present the evidence and rationale for the final assessment clearly and logically**
  - **Explain how the material was used or interpreted to make the assessment**
    - **Evidence could include records of tests/applications of the technology, technical papers, reports, presentations, and so forth**
  - **Reference the sources and the pages in these sources for the evidence presented for determining the TRL**
    - **Vague references to test results or test documents are not sufficient**
    - **The report should rely upon a formally identified body of evidence, which must be either included or accessible**

# Component S&T Executive Contributions

- **Provide any other pertinent technical information in the TRA technical report**
  - **Material provided by the S&T Executive should be clearly differentiated from the material provided by the IRT**
- **TRA report cover letter**
  - **Indicate agreements or disagreements with the findings of the IRT**
  - **A PM's TRL assessments can also be included in the cover letter**

# TRAs Should Not Include Recommendations for a Particular Programmatic Decision

- **Example 1**
  - **"… as part of a risk mitigation plan, eight prototype vehicles with the system are undergoing testing. *Based on the results to date, the system is considered mature enough to enter low rate production*."**
- **Example 2**
  - **"… *the maturity of the critical technologies, along with the associated risk mitigation approaches, support entry into System Development and Demonstration (SDD)* …"**

# TRAs Should Not Include Recommendations for a Particular Programmatic Decision (Continued)

- **Example 3**
  - **"The Example 3 Product Manager identified two critical technologies for the readiness of the program to enter the design and development contract. *The opinion of the Example 3 Product Office is that these two critical technologies have matured to a TRL level sufficient for entry into the SDD contract. These two technologies will have matured to a TRL level sufficient to enter low rate initial production (LRIP) far ahead of schedule*."**
  - **"Evolution of a system's transmit/receive (T/R) module offers the best available alternative for this example to meet T/R module requirements in SDD. This effort is imperative to the success of SDD and is *true 'risk reduction.'* "**

# CAE TRA Coordination

- **CAE approval is an endorsement of the CTE list and the assessed TRLs only**
- **Maturity requirements**
  - **Subsystem demonstrated in relevant environment (TRL 6) for Milestone B**
  - **Prototype demonstrated in an operational environment (TRL 7) for Milestone C**
- **Three options if a technology is not mature**
  - **Request a delay for the Milestone review until all CTEs are at the requisite maturity level**
  - **Use alternative, mature technologies**
  - ***As a last resort*, carry immature technologies into the Milestone review and prepare a waiver (based on inability to meet national security objectives) that the MDA can submit to Congress**

**Acquisition Executive submits the TRA to DRD**

# DRD TRA Review

- **Results of initial review**
  - **Concur**
  - **Request revisions**
- **If revised, results of final review**
  - **Concur**
  - **Concur with reservations**
  - **Non-concur**
  - **Perform ITA**

**DRD informs MDA of the results**

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# PM Roles and Responsibilities

- **Plans and funds the program's risk reduction activities to ensure that CTEs reach the appropriate maturity levels**
- **Informs the Component S&T Executive of the need to conduct a TRA**
- **Funds the TRA evaluation for his program**
- **Designates a responsible individual in the program office to organize all TRA activities**
- **Prepares a draft TRA schedule and incorporates the approved version in the program's IMP and IMS**
- **Suggests to the Component S&T Executive the subject matter expertise needed to perform the TRA**
- **Ensures that the IRT is familiar with the program**
- **Identifies possible CTEs for IRT consideration**
- **Provides evidence of CTE maturity to the IRT for its assessment, including contractor data**
- **Provides technical expertise to the IRT as needed**
- **Drafts the section of the TRA report containing a brief description of the program (program/system overview, objectives, and descriptions)**

# Component S&T Executive Roles and Responsibilities

- **Directs the conduct of the TRA**
- **Coordinates on the TRA schedule**
- **Nominates SMEs to be on the IRT**
- **Provides the DRD the credentials of all prospective IRT members and sufficient information to confirm their independence from the program**
- **Trains IRT members on the TRA process**
- **Reviews the TRA report and prepares the TRA report cover memo-randum, which may include additional technical information deemed appropriate to support or disagree with IRT findings**
- **Sends the completed TRA to the CAE for official transmittal to the DRD and furnishes an advance copy to the DRD**
- **Maintains continuity in the IRT membership for all TRAs conducted over the life of a program, to the maximum extent possible**

# IRT Roles and Responsibilities

- **Keeps the Component S&T Executive and the DRD informed on progress throughout the entire TRA process**
- **Develops a list of CTE candidates in conjunction with the PM**
- **Assesses the TRLs for all CTEs**
- **Prepares (or oversees the preparation of) elements of the TRA report including (1) the IRT credentials and (2) IRT deliberations, findings, conclusions, and supporting evidence**
  - **The assessment process should not be constrained to a validation of a "program-developed" position on the TRL**

# DRD Roles and Responsibilities

- **Concurs with the TRA schedule**
- **Concurs with the composition of the IRT**
- **Reviews the candidate CTE list and identifies any changes necessary to form the final CTE list. Additions to the list can include any special-interest technologies that warrant the rigor of the formal TRA process**
- **Exercises oversight by monitoring and evaluating the TRA process and reviewing the TRA. On the basis of that review, a TRA revision may be requested or the DRD may conduct its own Independent Technical Assessment (ITA)**
- **Sends the results of its TRA review to the appropriate Overarching Integrated Product Team (OIPT) and/or the Defense Acquisition Board (DAB)**
- **Provides the DDR&E recommendations concerning certification**
- **Recommends technology maturity language for an Acquisition Decision Memorandum (ADM), noting, in particular, conditions under which the new technology can be inserted into the program**

# Basis of Technology Maturity Assessments Throughout Acquisition

| | Milestone A | Milestone B | Milestone C |
|---|---|---|---|
| Basis of CTE Identification | Early evaluation of technology maturity | Current level of design and Capabilities Development Document (CDD) requirements | Planned LRIP article (or limited deployment version of an IT system), prior TRAs, and final design |
| CTE Identification Status | Potential CTEs | CTEs – actual technologies in a preliminary design | CTEs of planned LRIP articles (or limited deployment version of an IT system) |
| Assessment Method | Evaluated in early evaluations of technology maturity and Technology Maturation Plans (TMPs) | Assessed in Milestone B TRA | Assessed in Milestone C TRA |
| Documentation | Informal submission to DRD and corresponding updates to TDS appendix | Milestone B TRA | Milestone C TRA |

# References and Resources

- **Defense Acquisition Resource Center**
  **(https://dap.dau.mil/policy/Pages/overview.aspx)**
  - **DoD Directive (DoDD) 5000.01,*The Defense Acquisition System*, certified current as of November 20, 2007**
  - **DoD Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System*, dated December 8, 2008**
  - ***Defense Acquisition Guidebook***
- ***Defense Acquisition University (DAU )Continuous Learning Module CLE021* (https://learn.dau.mil/html/clc/Clc.isp)**
- ***Technology Readiness Assessment (TRA) Deskbook***
  **(http://www.dod.mil/ddre/doc/DoD_TRA_July_2009_Read_Version.pdf)**
- **Institute for Defense Analyses (IDA)**
  - **Dr. Dave Sparrow (dsparrow@ida.org)**
  - **Dr. Jay Mandelbaum (jmandelb@ida.org)**
  - **Dr. Michael May (mmay@ida.org)**

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See the bottom of Slide 26

# Sample Questions To Help Identify CTEs for an Aircraft (Aerodynamic Configuration)

- **Does the design incorporate a configuration that has not been used in flight?**
- **How similar is the configuration to that of aircraft that are successful?**
- **Does the configuration impose limitations on control authority, stability, structural rigidity, or strength?**
- **Is stability acceptable at high angles of attack?**
- **Is stability and control acceptable during configuration changes in flight?**

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# Sample Questions To Help Identify CTEs for a Networked Communication System

- Do the requirements for throughput, data latency, security or reliability imply that a new or novel technology is required?
- Have the network routers been used before within the required performance envelope?
- Are new or novel media access control, coding, or routing algorithms needed?
- Is the multiplexing schema new?
- Is the topology (logical and hardware) new?
- Do the peak and average data rates require new hardware or algorithms in the system?

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# Attainment of Technology Readiness for Hardware CTEs

| Accomplishment | TRL Supported | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Discovery of physical or mathematical principle | X | | | | | | | | |
| Characterization of the principle | X | | | | | | | | |
| Application envisioned and described | | X | | | | | | | |
| Concept of application analyzed | | X | | | | | | | |
| Critical functionality empirically confirmed | | | X | | | | | | |
| Proof of concept demonstrated in laboratory | | | X | | | | | | |
| Scale-up or other extension as needed by concept | | | X | X | | | | | |
| Breadboard or component tested in laboratory | | | | X | | | | | |
| Producibility and cost estimated | | | | X | X | | | | |
| Engineering Development Model (EDM) of component tested in laboratory | | | | X | | | | | |
| EDM of component tested in relevant environment | | | | | X | | | | |
| Prototype component integrated into a system EDM | | | | X | X | | | | |
| System EDM tested in simulated environment | | | | X | | | | | |
| System tested in limited field experiments | | | | X | X | | | | |
| System tested in relevant environment | | | | | | X | | | |
| System tested in operational environment | | | | | | | X | | |
| Production system tested in operational environment | | | | | | | | X | |
| Production system proven in mission operations | | | | | | | | | X |

**Note:** This is not a comprehensive checklist.
It only provides examples of supporting knowledge-based events.

Return

# Attainment of Technology Readiness for Software CTEs

| Accomplishment | TRL Supported | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Discovery of mathematical principle or algorithm | X | | | | | | | | |
| Characterization of the principle | X | | | | | | | | |
| Application envisioned and described | | X | | | | | | | |
| Concept of application analyzed | | X | | | | | | | |
| Critical functionality empirically confirmed and implemented software | | | X | | | | | | |
| Proof of concept demonstrated in simulation | | | X | | | | | | |
| Scale-up or other extension as needed by concept | | | X | X | | | | | |
| Component tested in simulation | | | | X | | | | | |
| Producibility and cost estimated | | | | X | X | | | | |
| Software component tested in an integration laboratory | | | | X | | | | | |
| Software component tested in a relevant environment | | | | | X | | | | |
| Prototype component integrated into a system prototype | | | | X | X | | | | |
| System tested in a simulated environment | | | | X | | | | | |
| System tested in a limited field experiments | | | | X | X | | | | |
| System tested in a relevant environment | | | | | | X | | | |
| System tested in an operational environment | | | | | | | X | | |
| Production system tested in an operational environment | | | | | | | | X | |
| Production system proven in mission operations | | | | | | | | | X |

**Note:** This is not a comprehensive checklist.
It only provides examples of supporting knowledge-based events.

Return

# IT TRA Challenges

- TRA/TRL model derived for hardware-oriented systems
- Increasing number of defense acquisitions are software intensive
  - Few hardware or software elements can be singled out as CTEs
- New IT issues include
  - Interfaces
  - Throughput
  - Scalability
  - External dependencies
  - Process reengineering
  - Information assurance
- Environment/architecture plays a greater role

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# Software-Intensive Systems Fall Into Five Broad Areas

- Information Systems and Business Systems
- Networked Communications Systems
- Mission Planning Systems
- Embedded IT in Tactical Systems

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# Information Systems and Business Systems

- **Challenges**
  - **Large COTS applications**
  - **Integration with legacy business applications**
  - **Integration in final environment**
  - **Data management**
  - **End-to-end responsiveness**
  - **Scalability**
- **Recommendations**
  - **Start with lists of COTS products**
    - **Focus on critical applications used in a new or novel way**
    - **Use pilot experience to justify TRLs of 6 and above**
  - **Include integrating technologies where applicable**
  - **Pay attention to DoD-unique environments**
  - **Address system-level issues**
    - **Responsiveness, scalability, and so forth**

# Networked Communications Systems

- Challenges
  - Services' focus
  - Consolidation of user needs and anticipated growth
  - Managing standards
  - Technology rollover
    - Ability to provide services
    - May transcend individual products
- Information assurance

- Recommendations
  - Start with technologies that enable one or more services
  - Avoid process issues except where enabled by technology
    - Roll-out, configuration management
  - Establish Technology Transition Agreements (TTAs) where DoD needs are not met by commercial technologies (e.g., mobile ad-hoc network protocols)
  - Consider market capabilities as well as specific technologies

# Mission Planning Systems

- **Challenges**
  - **Reliance on external data sources**
  - **Mixed COTS/GOTS components**
  - **Infrastructure upkeep and modernization**
  - **Technology turnover**
  - **Scalability and responsiveness**
- **Recommendations**
  - **Start with required functionality and supporting technologies**
  - **Identify critical data dependencies on external programs**
  - **Assess ability to succeed based upon total suite of data suppliers/ users and infrastructure, not just application maturity**

# Embedded IT in Tactical Systems

- **Challenges**
  - **Lots of developed software**
  - **Military-unique environments**
    - **Radiation hardened, shock/vibration, high reliability**
  - **Military-unique functionality**
    - **IT as an enabler**
- **Recommendations**
  - **Start with function domains or WBS**
  - **IT typically not a CTE except where consolidated computing requirements are used**
  - **For COTS, carefully examine relevant and operational environment success when rating technology readiness**
  - **Do not address developer capabilities in assessing technology maturity**

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# How TRAs Got Started

- **"Program managers' ability to reject immature technologies is hampered by (1) untradable requirements that force acceptance of technologies despite their immaturity and (2) reliance on tools that fail to alert the managers of the high risks that would prompt such a rejection." (GAO/NSIAD-99-162)**
- **"Identify each case in which a major defense acquisition program entered system development and demonstration … into which key technology has been incorporated that does not meet the technology maturity requirement … and provide a justification for why such key technology was incorporated and identify any determination of technological maturity with which the Deputy Under Secretary of Defense for Science and Technology did not concur and explain how the issue has been resolved." (National Defense Authorization Act for Fiscal Year 2002)**
- **"The management and mitigation of technology risk, which allows less costly and less time-consuming systems development, are crucial parts of overall program management and is especially relevant to meeting cost and schedule goals. Objective assessment of technology maturity and risk shall be a routine aspect of DoD acquisition." (DoDI 5000.2, Enclosure 2, paragraph 5.d(4))**

**Stop launching programs before technologies are mature**

# Best Practices for a Preliminary TRA at Milestone A (Only Applies to Ships)

***Example***

- **Use the TRA to identify areas for management focus**
  - **Create critical technology IPTs**
- **No contract award yet**
  - **Update the TRA after a selection decision**
- **No TRL requirements**
  - **TRL of 3 or lower implies higher technology risk**
  - **Technology Development Phase generally mature technology from TRL 4 to TRL 6**
  - **Use TTA**

# Nature of the TRA at Milestone C

- **Start where Milestone B TRA left off**
- **Use the same IRT that was used at the TRA at Milestone B**


- **Based upon the detailed design documentation in the product baseline**
  - **Determine if any new CTEs have emerged**
  - **Pay careful attention to operational environment implications, especially for COTS products**
  - **Assess maturity**
    - **Performance-related CTEs should be at least TRL 7**


# IRT Information Needs

- **Program overview to set the foundation for the CTE assessments**
  - **Concept of operations (CONOPS)**
  - **Program master schedule**
    - **Identify significant milestones, items on the critical path, and status of progress**
  - **Operational performance requirements**
    - **Highlight KPPs in general and those operational requirements that will be directly influenced by the CTEs to be assessed**
  - **The challenges associated with the CTEs to be assessed**
  - **Technology maturation roadmap**
    - **Highlight those maturation events that have been accomplished and those that have yet to occur**
  - **Overall system architecture**
    - **Highlight the CTE system/subsystem elements that will be assessed**


# IRT Information Needs (Continued)

- **Introduction to the subsystems containing the CTEs**
  - **Technical description of the subsystem, to include physical architecture, highlighting CTEs (components and/or packaging): explain why other technologies within subsystem are non-critical and differentiate subsystem and elements from those of potentially similar designs (i.e., highlight any uniqueness)**
  - **Description of the subsystem's intended function in the design**
    - **Significance of the CTEs relative to the subsystem**
    - **Significance of the subsystem relative to the system overall design**
    - **Traceability of the subsystem relative to the applicable operational requirements. State whether subsystem will impact a KPP**
  - **Schedule for the design and integration of the subsystem, clearly identifying critical path events and, if relevant, expectation/deliveries from suppliers**
  - **Block diagram and risk assessment for the subsystem**
  - **Roadmap of ongoing and planned maturation activities and how these events can influence the master design schedule**


# IRT Information Needs (Continued)

- **Status of CTE**
  - **Accomplishments that directly reflect CTE maturation**
    - **Use TRL rating factors as a guideline**
    - **State quantitative facts where possible to temper and legitimize the significance of the technology maturation accomplishments**
    - **Describe the measurement environment and methodology used**
    - **Identify who witnessed the subsystem/technology maturation accomplishments**
  - **Tangible evidence of CTE maturation accomplishments (e.g., hardware, pictures, displays, technical papers, reports, and so forth)**
    - **Clearly state what is and is not represented by the evidence**
  - **Relevant CTE maturation leveraged from other programs**
    - **Clearly state any differences between this program and the leveraged program, to appreciate significance of maturation events**
  - **Significant maturation events that fall short or have not been accomplished**

# Preconditions for Entering EMD With Immature CTEs

- **MDA submits waiver to Congress describing why waiving these requirements was necessary to meet national security objectives**
- **A sound technical basis exists for expecting the immature technology to prove adequate after a demonstration**
- **If the demonstration is unsuccessful, a substitute *mature* technology is available and can be used**
- **The program plan can accommodate use of either technology from funding, performance, and schedule perspectives**

# How the S&T Community Can Best Support the TRA Process

# Use of TRA and TRL Terminology
## *Acquisition Community*

- **TRAs help ensure that the technology being used in acquisition programs is mature**
  - **Use of immature technologies leads to cost growth and schedule slippage**
- **TRAs provide the basis for DDR&E to advise the MDA on 10 U.S.C. 2366b certification for technology maturity at Milestone B/KDP B**
- **TRLs are the maturity metric for CTEs in TRAs. TRLs 5–9 are applicable**
  - **Environments and the performance requirements defined by a program of record**
- **TRAs performed at Milestones B and C and at program initiation for ships**

# Use of TRA and TRL Terminology
## *S&T Community*

- **TRAs are an acquisition construct**
  - **They are not performed on an S&T project**
- **TRLs may be used as a maturity metric for technologies in a technology development project. TRLs 1–6 are applicable**
  - **TRL definitions and descriptions successively spell out progress (as measured by tests) toward a goal**
- **TRLs may be used as part of a technology managers' ongoing assessment of a technology or technologies**

**Use of TRLs 5 and 6 overlaps with the acquisition community**

# Issues Arising From an Overlap in Terminology

- **Normally, demonstrating a technology beyond TRL 4 requires more resources than maturing the technology through TRLs 1–3**
  - **Higher level assemblies needed**
  - **More refined components are needed**
  - **More broad scale tests are needed**
- **Such resources often obtained from programs of record as activities shift from the realm of technology advancement to technology transition and insertion**
- **Misunderstanding of TRLs 5 and 6 has led to misuse of the terminology when competing for these resources**
  - **May damage the S&T program and/or the TRA process**
  - **May create the wrong impression with leadership**

**Misuse of TRA and TRL terminology and concepts may lead to negative unintended consequences**

# TRL 4 Is the Breakpoint Between Invention and Application

- **TRLs 1–3 involve development of functionality, mostly independent of the application**
- **To achieve TRL 4**
  - **Must begin integration of components to represent how they would be used in a fieldable application**
  - **Must have a generic application in mind without knowing exactly how that application will be used**

# TRL 4 Is the Breakpoint Between Invention and Application (Continued)

- **To achieve TRL 5 or higher**
  - **Must be in the context of an application for a program of record**
    - **The application provides the both the metric (speed, energy density …) and the threshold (10 m/s, 100J/g …)**
  - **Must have an understanding of the relevant environment**
    - **The relevant environment cannot be determined without an understanding of requirements and intended operational use, as defined in programmatic documents**

# TRL 4 Is the Breakpoint Between Invention and Application (Continued)

- **Gun propellant example**
  - **TRL 1: Theoretical studies and computer models lead to synthesis and characterization of a new energetic material for a propellant**
  - **TRL 2: New material synthesized and characterized, and potential performance of propellants mapped via computer codes**
  - **TRL 3: New propellants prepared at small scale, and performance, processing, and physical properties characterized**
  - **TRL 4: Based on TRL 1–3 data, propellant designed for a specific application and near-full-scale tests performed to confirm computer modeling**
  - **TRL 5: New propellant produced in quantity and evaluated in the near-final system configuration**

# Milestone B Requirement: Demonstration or Validation in a Relevant Environment (TRL 6)

**Relevant Environment: a *set of stressing conditions representative of the full spectrum of relevant operational employments*, which are applied to a CTE as part of a component (TRL 5) or system/subsystem (TRL 6) model or prototype *to identify whether any design changes or fixes are needed to support the required (threshold) functionality***

# Demonstration or Validation of a Technology in a Relevant or Operational Environment

- **Requires successful trial testing that either**
  - **Shows that the technology satisfies functional need across the full spectrum of operational employments or**
  - **Shows that the technology satisfies the functional need for some important *(stressing)* operational employment and that it uses accepted techniques to extend confidence over all required operational employments**

# S&T Practices To Better Support TRAs and the Acquisition Process

- **Not labeling the technology assessments performed by the S&T community as a TRA**
  - **Misuses the term in a way that misleads stakeholders**
  - **May damage both TRA and technology proponent's reputation**
- **Not justifying the need for research (dollars) based on achieving TRL 5/6 without the metrics and the threshold provided by a program of record**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

- **Applying judgment when trying to differentiate the relevant environment from the operational environment to maximize test efficiency**
  - **Environments tested should be stressing enough to be persuasive**
    - **Being exhaustive is usually too expensive**

## *Example*

- **Launching a satellite should not be on the critical path for design and demonstration**
- **Relevant environment depends on what is stressing**
  - **For example, thermal load, radiation in space, g-forces during launch**
  - **Can be tested and demonstrated in the lab**
- **Technical expertise ensures that the stressing portion of the environment is demonstrated. No expensive, exhaustive tests applied to non-critical elements**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

- **Continuing promising technology development at TRL 4 when there is no program of record**
  - **While TRLs 5/6 are achieved with a successful demonstration, a large number of useful activities could take place at TRL 4**
    - **Completing an extensive performance characterization rather than a "point demonstration" is helpful**
      - **Provides information on how to incorporate the technology into a design**
      - **Enables more rapid insertion**
      - **Supports knowledge-based acquisition decisions**
    - **A technology's capability can be advanced using metrics of interest without knowing the particular thresholds**
    - **Improvements can be planned on the basis of draft requirements**

**Continuing development also applies to TRL 5/6**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

- **Preparing to help programs of record achieve TRLs 5/6 via expertise with the technology and the test design, as they reach back to the tech base for solutions**
  - **Neither labs nor program offices are organized or staffed to conduct the realistic demonstrations of highly integrated components needed to mature technologies to TRL 5/6**
  - **S&T personnel (and institutions) should transition into a supporting role**

## *Example*

- **Armor-piercing, Fin-stabilized Discarding Sabot (APFSDS) had nearly maxed performance capabilities**
- **The 1984 Armament Enhancement Initiative was established to reduce sabot weight (partnership between S&T and acquisition)**
- **By 1987, requirement had been established for new composite sabot, which was fielded in 1992**
- **Cycle repeated itself for fielding a more advanced sabot in 2003**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

- **Differentiating proof-of-principle demonstration (TRL 3) from demonstration in a (requirements-defined) relevant environment (TRL 5/6)**
  - **For TRL 3: do not need to have an application in mind**
    - **Acquisition customer may say, "If you make it work, I'll use it"**
  - **For TRL 5: must be an application, and components must be representative of use in intended application**
  - **For TRL 6: ready to turn it over to a design engineer**

**Overselling technology readiness damages the S&T community credibility as much as overselling technology performance. May lead to . . .**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

**. . . acquisition problems if program initiated with immature technology**

***Example***

- **The regenerative liquid propellant gun (RLPG) ultimately became the CRUSADER program**
  - **When program transitioned from S&T, the concept was proven**
    - **All technology issues were reasonably well recognized**
    - **Plan was to solve the problems in engineering**
  - **Eventual failure (program cancellation) was associated with the difficulties encountered when transferring the technology to practical hardware**

# S&T Practices To Better Support TRAs and the Acquisition Process (Continued)

- **Avoiding the use of TRLs as a sole, governing measure for managing S&T programs**
  - **TRLs are a static metric and represent snapshot in time. TRLs do not assess difficulty of advancement**
  - **TRLs lack high specificity. Much more information needs to be conveyed**
    - **Should lay out specific technical goals to evaluate technology status/ progress**
  - **Could lead to a premature stoppage of development efforts as soon as next TRL is reached**
- **Using TRLs a high-level metric for managing a balanced portfolio of investments from basic research to exploratory development of components**
  - **Helps avoid under emphasis on basic principles or concept formulation (TRLs 1 and 2) in favor of research on proof of principle or demonstration in lab (TRLs 3 and 4)**

# Acquisition Practices To Improve Linkages With S&T

- **Developing (in conjunction with the S&T community) a TMP to identify how technologies will be demonstrated in a relevant environment by Milestone B**
- **Establishing measurable technical performance requirements as technology transition exit criteria to achieve TRL 6 for CTEs**
  - **Fully describe the relevant environment in TTAs**
  - **Include metrics and thresholds in a relevant environment**
  - **Do not specify TRL 6 as an exit criterion**

# Acquisition Practices To Improve Linkages With S&T (Continued)

- **Shifting necessary resources (funding and personnel) to the Technology Development Phase**
- **Accounting for the event-driven nature of S&T processes when developing schedules**
  - **Applying schedule-driven constraints may compromise technology development and lead to immature technologies at Milestone B**
  - **Backup plans and alternatives to technologies less than TRL 6 are advisable**

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This briefing was prepared as a training tool for the Independent Review Team (IRT) members who conduct Technology Readiness Assessments (TRAs). It also provides a useful introduction to others who are new to the TRA process. Several examples are offered to assist an IRP in selecting Critical Technology Elements (CTEs) and the necessary metrics for proper evaluation. The training materials are based on—and should be used in conjunction with—the Technology Readiness Assessment (TRA) Deskbook, which provides the Research Directorate's guidance and best practices for conducting TRAs.

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